TITLE OF THE INVENTION

VARIABLE CAPACITY ROTARY COMPRESSOR

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of Korean Application No. 2003-19060, filed March 27, 2003 and Korean Application No. 2004-15385, filed March 8, 2004 in the Korean Intellectual Property Office, the disclosures of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a variable capacity rotary compressor, and more particularly to a variable capacity rotary compressor capable of varying a refrigerant compression ability thereof in a multi-stage fashion within a wide range.

2. Description of the Related Art

Recently developed air conditioners and coolers of refrigerators have a function capable of varying a cooling capacity in accordance with a variation in cooling conditions (for example, the temperature of a confined space to be cooled, etc.) in order to achieve an optimal cooling operation while reducing energy consumption. For this function, such devices typically use a variable capacity rotary compressor configured to vary a refrigerant compression ability thereof.

Known variable capacity rotary compressors generally include a compressing device adapted to compress a refrigerant, and then to discharge the compressed refrigerant, and a drive motor adapted to drive the compressing device. For the drive motor of such a compressor, a general inverter motor or brushless DC (BLDC) motor may be used which can vary a rotating speed thereof, depending on a

variation in input electric power. That is, such a compressor can vary a refrigerant compression ability thereof, that is, a refrigerant compression capacity thereof, by varying the rotating speed of the drive motor in accordance with an operation for controlling input electric power to be applied to the drive motor.

However, such a variable capacity rotary compressor has a problem in that it is difficult to control the refrigerant compression capacity in a multi-stage fashion within a wide range because the control to vary the refrigerant compression capacity is carried out, using a method of operating the compressing device at a speed controlled by control of the rotating speed of the drive motor.

Since, when it is required to increase the compression capacity of the rotary compressor, the drive motor must rotate at high speed to operate the compressing device at high speed, rotational elements of the rotary compressor may be correspondingly rapidly worn. As a result, the lifespan of the drive motor and compressing device may be shortened. Also, where the rotating speed of the drive motor varies abruptly, the entire system of the rotary compressor may abnormally operate because the operating condition of the compressing device must vary abruptly. For example, supply of oil to the compressing device may be ineffectively achieved because the oil supply conditions in high-speed and low-speed operations are different from each other.

SUMMARY OF THE INVENTION

Therefore, it is an aspect of the invention to provide a variable capacity rotary compressor which is configured to achieve a variation in the capacity thereof by electrically controlling a drive motor thereof while using a particular mechanical structure of a compressing device thereof, thereby being capable of achieving the capacity variation in a multi-stage fashion within a wide range while reducing a variation in the rotating speed of a drive motor thereof.

Another aspect of the invention is to provide a variable capacity rotary compressor capable of achieving a variation in capacity in a multi-stage fashion

within a wide range without any overload to a drive motor thereof and a compressing device thereof.

In accordance with one aspect, the present invention provides a variable capacity rotary compressor comprising: a housing defined therein with first and second compressing chambers having different volumes; a rotating shaft adapted to rotate in the first and second compressing chambers; a compressing unit arranged in the first and second compressing chambers, and adapted to perform a compression operation in a selected one of the first and second compressing chambers in accordance with a change of a rotating direction of the rotating shaft; and a drive motor adapted to rotate the rotating shaft in a first direction or in a second direction, the drive motor being variable in rotating speed in accordance with an electrical control operation.

The compressing unit may comprise first and second sleeves respectively arranged in the first and second compressing chambers, first and second eccentric units mounted on the rotating shaft, and adapted to operate in opposite manners such that one of the first and second eccentric units selectively rotates an associated one of the first and second sleeves in an eccentric state in accordance with the rotating direction change of the rotating shaft, thereby causing the associated sleeve to perform a compression operation in an associated one of the first and second compressing chambers, while the other eccentric unit idly rotates the other sleeve associated therewith in the other compressing chamber associated therewith during the compression operation caused by the one eccentric unit, and first and second vanes respectively arranged in the first and second compressing chambers to be radially movable between extended positions thereof and retracted positions thereof.

The drive motor may be a brushless DC motor.

The drive motor may be an inverter motor.

The first eccentric unit may comprise a first eccentric cam fixedly fitted around an outer surface of the rotating shaft in the first compressing chamber, and a first eccentric bush rotatably fitted around an outer surface of the first eccentric cam.

The second eccentric unit may comprise a second eccentric cam fixedly fitted around the outer surface of the rotating shaft in the second compressing chamber, and a second eccentric bush rotatably fitted around an outer surface of the second eccentric cam. The compressing unit may further comprise a locking unit adapted to lock the first and second eccentric bushes in opposite states in accordance with the rotating direction change of the rotating shaft such that one of the first and second eccentric bushes is locked in an eccentric state, while the other eccentric bush is locked in an eccentricity-released state.

The compressing unit may further comprise a cylindrical connecting member adapted to connect the first and second eccentric bushes such that the first and second eccentric bushes have opposite eccentric directions. The locking unit may comprise a locking slot provided at the connecting member to extend circumferentially, and a locking pin extending radially through the locking slot to be coupled to the rotating shaft such that the locking pin is engagable with the locking slot.

The first vane may be arranged between suction and discharge ports of the first compressing chamber to be radially movable between an extended position thereof and a retracted position thereof while being in contact with an outer surface of the first sleeve. The second vane may be arranged between suction and discharge ports of the second compressing chamber to be radially movable between an extended position thereof and a retracted position thereof while being in contact with an outer surface of the second sleeve.

In accordance with another aspect, the present invention provides a variable capacity rotary compressor comprising: a housing defined therein with first and second compressing chambers having different volumes; a rotating shaft adapted to rotate in the first and second compressing chambers; first and second sleeves respectively arranged in the first and second compressing chambers; an eccentric unit mounted on the rotating shaft, and adapted to operate the first and second sleeves such that one of the first and second sleeves rotates in an eccentric state when the rotating shaft rotates in a first direction, thereby performing a

compression operation, while the other sleeve idly rotates during the compression operation, whereas, when the rotating shaft rotates in a second direction, the first and second sleeves perform operations opposite to the operations carried out when the rotating shaft rotates in the first direction, respectively; and a drive motor adapted to rotate the rotating shaft in a first direction or in a second direction, the drive motor being variable in rotating speed in accordance with an electrical control operation.

BRIEF DESCRIPTION OF THE DRAWINGS

The above aspects, and other features and advantages of the present invention will become more apparent after reading the following detailed description when taken in conjunction with the drawings, in which:

FIG. 1 is a sectional view illustrating a configuration of a variable capacity rotary compressor according to the present invention;

FIG. 2 is a perspective view illustrating a configuration of an eccentric unit included in the variable capacity rotary compressor according to the present invention;

FIG. 3 is a cross-sectional view illustrating a compression operation in a first compressing chamber when a rotating shaft of the variable capacity rotary compressor according to the present invention rotates in a first direction;

FIG. 4 is a cross-sectional view illustrating an idle rotation in a second compressing chamber when the rotating shaft of the variable capacity rotary compressor according to the present invention rotates in the first direction;

FIG. 5 is a cross-sectional view illustrating an idle rotation in the first compressing chamber when the rotating shaft of the variable capacity rotary compressor according to the present invention rotates in a second direction;

FIG. 6 is a cross-sectional view illustrating a compression operation in the second compressing chamber when the rotating shaft of the variable capacity rotary compressor according to the present invention rotates in the second direction; and

FIG. 7 is a table showing a variation in compression capacity depending on a variation in the operation condition of the variable capacity rotary compressor

according to the present invention.

DETAILED DESCRIPTION OF ILLUSTRATIVE, NON-LIMITING EMBODIMENTS OF THE INVENTION

An illustrative, non-limiting embodiment of the present invention will now be described in detail with reference to the annexed drawings.

Referring to FIG. 1, a variable capacity rotary compressor according to an exemplary embodiment of the present invention is illustrated. The variable capacity rotary compressor includes a hermetic casing 10, a drive motor 20 installed in the casing 10 at an upper portion of the casing 10, and adapted to generate a rotating force, and a compressing device 30 installed in the casing 10 at a lower portion of the casing 10, and connected to the drive motor 20 via a rotating shaft 21.

The drive motor 20 includes a cylindrical stator 22 fixedly mounted to an inner surface of the casing 10, and a rotor 23 rotatably mounted in the stator 22, and coupled, at a central portion thereof, to the rotating shaft 21. The drive motor 20 may comprise a variable speed motor configured to be rotatable in forward and reverse directions while being capable of controlling a rotating speed thereof. For such a variable speed motor, an inverter motor or BLDC motor may be used which can vary a rotating speed thereof in accordance with an electrical control operation. As the rotating speed of the drive motor 20 increases or decreases in accordance with the electrical control operation, the operating speed of the compressing device 30 is controlled to vary the compression capacity of the rotary compressor.

The compressing device 30 includes upper and lower housings 31 and 32 vertically arranged while defining therein first and second cylindrical compressing chambers 31 and 32 having different volumes, an intermediate plate 34 arranged between the upper and lower housings 33a and 33b to partition the first and second compressing chambers 31 and 32. The compressing device 30 also includes upper and lower flanges 35 and 36 adapted to close the top of the first compressing

chamber 31 and the bottom of the second compressing chamber 32, respectively, while rotatably supporting the rotating shaft 21. The upper and lower flanges 35 and 36 are mounted to an upper end of the upper housing 33a and a lower end of the lower housing 33b, respectively.

The compressing device 30 further includes a compressing unit arranged in the first and second compressing chambers 31 and 32, and adapted to perform a compression operation in the first or second compressing chambers 31 and 32 in accordance with rotation of the rotating shaft 21 in such a manner that the compression operation is carried out in only a selected one of the first and second compressing chambers 31 and 32, depending on the rotating direction of the rotating shaft 21. As shown in FIGS. 2 to 4, the compressing unit includes first and second eccentric units 40 and 50 vertically arranged to be disposed in the first and second compressing chambers 31 and 32, respectively, while being mounted on the rotating shaft 21, and first and second sleeves 37 and 38 rotatably arranged around the eccentric units 40 and 50. The compressing unit also includes a first vane 61 arranged between suction and discharge ports 63 and 65 of the first compressing chamber 31 such that it moves radially to extend into or retract from the first compressing chamber 31 in a state of being in contact with an outer surface of the sleeve 37 during a compression operation carried out in the first compressing chamber 31. The compressing unit further includes a second vane 62 arranged between suction and discharge ports 64 and 66 of the second compressing chamber 32 such that it moves radially to extend into or retract from the second compressing chamber 32 in a state of being in contact with an outer surface of the sleeve 38 during a compression operation carried out in the second compressing chamber 32. The vanes 61 and 62 are elastically supported by first and second vane springs 61a and 62a. The suction and discharge ports 63 and 65 of the first compressing chamber 31 are arranged at opposite sides of the vane 61, respectively, whereas the suction and discharge ports 64 and 66 of the second compressing chamber 32 are arranged at opposite sides of the vane 62, respectively.

The first eccentric unit 40 includes a first eccentric cam 41 fixedly fitted, in

an eccentric state, around a portion of the rotating shaft 21 arranged in the first compressing chamber 31, and an upper or first eccentric bush 42 rotatably fitted around the eccentric cam 41. Similarly, the second eccentric unit 50 includes a second eccentric cam 51 fixedly fitted, in an eccentric state, around a portion of the rotating shaft 21 arranged in the second compressing chamber 32 while having the same eccentric direction as the first eccentric cam 41, and a lower or second eccentric bush 52 rotatably fitted around the eccentric cam 51. As shown in FIG. 2, the first and second eccentric bushes 42 and 52 are connected by a cylindrical connecting member 43 such that they are integral while having opposite eccentric directions, respectively. The first and second sleeves 37 and 38 are rotatably fitted around the first and second eccentric bushes 42 and 52, respectively.

As shown in FIG. 2, an eccentric member 44 is also fixedly fitted, in an eccentric state, around the rotating shaft 21 between the first and second eccentric cams 41 and 51 while having the same eccentric direction as that of the eccentric cams 41 and 51. The connecting member 43 is rotatably fitted around the eccentric member 44. A locking unit 80 is arranged between the connecting member 43 and the eccentric member 44 to cause one of the eccentric bushes 42 and 52 to be rotated along with the rotating shaft 21 in an eccentric state while causing the other eccentric bush to be rotated along with the rotating shaft 21 in an eccentricity-released state, in accordance with the rotation direction of the rotating shaft 21. The locking unit 80 includes a locking pin 81, and a locking slot 82. The locking slot 82 is formed at the connecting member 43 such that it extends circumferentially by a desired length. The locking pin 81 extends radially through the locking slot 82, and is threadedly coupled with a threaded hole formed at a flat portion of the outer surface of the eccentric member 44 at one side of the eccentric member 44. In accordance with rotation of the rotating shaft 21, the locking pin 81 is engaged with the locking slot 82 at a position where the first eccentric bush 42 is locked in an eccentric state, and the second eccentric bush 52 is locked in an eccentricity-released state, or at another position where the first eccentric bush 42 is locked in an eccentricity-released state, and the second eccentric bush 52 is locked in an eccentric state. That is, when the rotating shaft 21 rotates by a certain angle under

the condition in which the locking pin 81 is coupled to the eccentric member 44, and thus, the rotating shaft 21, through the locking slot 82, the locking pin 81 is engaged with one of opposite ends 82a and 82b of the locking slot 82, so that both the eccentric bushes 42 and 52 are rotated, along with the rotating shaft 21. In accordance with such an engagement of the locking pin 81 with the locking slot 82, one of the eccentric bushes 42 and 52 is locked in an eccentric state thereof, whereas the other eccentric bush is locked in an eccentricity-released state thereof. As a result, a compression operation is carried out in one compressing chamber 31 or 32 associated with the eccentric bush 42 or 52 locked in an eccentric state thereof, whereas an idle rotation is carried out in the other compressing chamber 32 or 31 associated with the eccentric bush 52 or 42 locked in an eccentricity-released state thereof. When the rotating direction of the rotating shaft 21 is changed, respective locked states of the eccentric bushes 42 and 52 are reversed.

As shown in FIG. 1, the variable capacity rotary compressor according to the illustrated embodiment of the present invention also includes a flow path change device 70 adapted to change a suction flow path so that a refrigerant from a suction conduit 69 can be sucked into the suction port of the compressing chamber where a compression operation is carried out, that is, the suction port 63 of the first compressing chamber 31 or the suction port 64 of the second compressing chamber 32.

The flow path change device 70 includes a cylindrical body 71, and a valve unit arranged in the cylindrical body 71. The cylindrical body 71 is provided, at a central portion thereof, with an inlet 72, to which the suction conduit 69 is connected. The cylindrical body 71 is also provided, at opposite sides thereof, with first and second outlets 73 and 74, to which conduits 67 and 68 connected to respective suction ports 63 and 64 of the first and second compressing chambers 31 and 32 are connected, respectively. The valve unit arranged in the cylindrical body 71 includes a cylindrical valve seat 75 arranged at the central portion of the cylindrical body 71, first and second valve members 76 and 77 respectively arranged at opposite lateral portions of the cylindrical body 71 such that they are movable toward or away from

opposite ends of the valve sheet 75 to close or open the opposite ends of the valve sheet 75, and a connecting member 78 adapted to connect the first and second valve members 76 and 77 such that the first and second valve members 76 and 77 are movable together. When a compression operation is carried out in the first or second compressing chamber 31 or 32, a pressure difference is generated between the outlets 73 and 74, thereby causing the first and second valve members 76 and 77 to move toward a lower pressure side in the cylindrical body 71. Thus, the flow path change device 70 automatically changes the suction flow path.

Now, the mechanical capacity varying operation of the compressing device carried out depending on a change in the rotating direction of the rotating shaft in the above described variable capacity rotary compressor will be described.

When the rotating shaft 21 rotates in a first direction (counterclockwise direction), as shown in FIG. 3, the locking pin 81 is engaged with the end 82b of the locking slot 82 in a state in which the outer surface of the first eccentric bush 42 in the first compressing chamber 31 is eccentric to the rotating shaft 21. Accordingly, the first sleeve 37 rotates while coming into contact with the inner surface of the first compressing chamber 31. Thus, a compression operation is carried out in the first compressing chamber 31. In this case, the outer surface of the second eccentric bush 52 in the second compressing chamber 32 is concentric to the rotating shaft 21, so that the second sleeve 38 is maintained in a state of being spaced apart from the inner surface of the second compressing chamber 32. Thus, an idle rotation is carried out in the second compressing chamber 32. During the compression operation in the first compressing chamber 31, a refrigerant is sucked only into the first compressing chamber 31 through the suction port 63 in accordance with the operation of the flow path change device 70.

These operations are enabled because the first and second eccentric cams 41 and 51 have the same eccentric direction, whereas the first and second eccentric bushes 42 and 52 have opposite eccentric directions, respectively, that is, because when the maximum eccentric portions of the first eccentric cam 41 and first eccentric bush 42 have the same direction, the maximum eccentric portions of the second

eccentric cam 51 and second eccentric bush 52 have opposite directions, respectively.

On the other hand, when the rotating shaft 21 rotates at the same speed as that of the above case in a second direction (clockwise direction) reverse to that of the above case to perform a compression operation, as shown in FIG. 5, the locking pin 81 is engaged with the end 82a of the locking slot 82 in a state in which the outer surface of the first eccentric bush 42 in the first compressing chamber 31 is released from the eccentric state thereof to the rotating shaft 21. Accordingly, the first sleeve 37 is maintained in a state of being spaced apart from the inner surface of the first compressing chamber 31, so that an idle rotation is carried out in the first compressing chamber 31. In this case, the outer surface of the second eccentric bush 52 in the second compressing chamber 32 is eccentric to the rotating shaft 21, as shown in FIG. 6. Accordingly, the second sleeve 38 rotates while coming into contact with the inner surface of the second compressing chamber 32. Thus, a compression operation is carried out in the second compressing chamber 32. During the compression operation in the second compressing chamber 32, a refrigerant is sucked only into the second compressing chamber 32 in accordance with the operation of the flow path change device 70.

Thus, it is possible to achieve a variation in capacity in accordance with the mechanical operation of the compressing device 30 caused by simply changing the rotating direction of the rotating shaft 21 in accordance with the present invention. That is, where a compression operation is carried out in the second compressing chamber 32 as the rotating shaft 21 rotates in the second direction, a reduction in compression capacity is achieved even under the condition in which the drive motor 20 rotates at the same speed as that in the compression operation in the first compressing chamber 31. This is because the second compressing chamber 32 has a volume smaller than that of the first compressing chamber 31. For example, where the second compressing chamber 32 has a volume corresponding to 50% of the volume of the first compressing chamber 31, it has a compression capacity corresponding to 50% of the compression capacity of the first compressing chamber

31 under the condition in which the rotating speed of the drive motor 20 is constant.

In accordance with the present invention, it is also possible to control the variation in the compression capacity of the rotary compressor in a multi-stage fashion within a wide range by not only implementing the above described mechanical capacity variation of the compressing device 30, but also implementing a variation in capacity through control of the rotating speed of the drive motor 20. That is, the compression capacity of the rotary compressor can be controlled in a multi-stage fashion with a wide range by varying the frequency of input electric power, to be applied to the drive motor 20, within a range of 20 to 120 Hz to control the rotating speed of the drive motor 20, while changing the rotating direction of the drive motor 20.

For example, where the volume of the second compressing chamber 32 corresponds to 50% of the volume of the first compressing chamber 31, the frequency of input electric power to be applied to the drive motor 20 is controlled to be 20Hz, 60Hz, and 120Hz, in order to control the rotating speed of the drive motor 20 to be a low speed, a medium speed, and a high speed, respectively, and the rotating direction of the drive motor 20 is controlled to be a first or second direction, a multi-stage capacity variation within a wide range may be achieved, as described in a table of FIG. 7. The results of FIG. 7 represent relative compression capacity variations under various operation conditions achieved when a compression operation is carried out in the first compressing chamber 31 as the drive motor 20 rotates in the first direction, and it is assumed that the compression capacity obtained at the medium rotating speed (60Hz) corresponds to 100%.

The first example in FIG. 7 corresponds to the case in which a compression operation is carried out in the first compressing chamber 31 as the drive motor 20 rotates in the first direction (counterclockwise direction in FIG. 3), and the rotating speed of the drive motor 20 is controlled to be the low speed (20Hz). In this case, a compression capacity corresponding to 33% of the second example in FIG. 7 is obtained.

The second example corresponds to the case in which a compression operation is carried out in the first compressing chamber 31 as the drive motor 20 rotates in the first direction, and the rotating speed of the drive motor 20 is controlled to be the medium speed (60Hz). In this case, a compression capacity of 100% is obtained.

The third example corresponds to the case in which a compression operation is carried out in the first compressing chamber 31 as the drive motor 20 rotates in the first direction, and the rotating speed of the drive motor 20 is controlled to be the high speed (120Hz). In this case, a compression capacity corresponding to 200% of the second example is obtained.

The fourth example corresponds to the case in which a compression operation is carried out in the second compressing chamber 32 as the drive motor 20 rotates in the second direction (clockwise direction in FIG. 6), and the rotating speed of the drive motor 20 is controlled to be the low speed (20Hz). In this case, a compression capacity corresponding to 16.6% of the second example is obtained.

The fifth example corresponds to the case in which a compression operation is carried out in the second compressing chamber 32 as the drive motor 20 rotates in the second direction, and the rotating speed of the drive motor 20 is controlled to be the medium speed (60Hz). In this case, a compression capacity corresponding to 50% of the second example is obtained.

The sixth example corresponds to the case in which a compression operation is carried out in the second compressing chamber 32 as the drive motor 20 rotates in the second direction, and the rotating speed of the drive motor 20 is controlled to be the high speed (120Hz). In this case, a compression capacity corresponding to 100% of the second example is obtained.

Thus, in accordance with the present invention, it is possible to achieve a multi-stage capacity variation within a wide range, as compared to conventional cases, by not only implementing a mechanical capacity variation of the compressing device 30 through a change of the rotating direction of the drive motor 20, but also

implementing a variation in capacity through control of the rotating speed of the drive motor 20.

In particular, as shown in FIG. 7, the compression capacity obtained under the operation condition of the second example is equal to the compression capacity obtained under the operation condition of the sixth example. In either case, accordingly, the same result is obtained. However, it is preferred that the operation condition of the second example be selected in that it is possible, in this case, to prevent the elements of the compressor from being overloaded by virtue of a lower rotating speed of the drive motor 20, thereby extending the lifespan of those elements, while obtaining the same compression capacity. Thus, in accordance with the present invention, it is possible to select, from a plurality of operation conditions providing the same compression capacity, an operation condition capable of minimizing an overload applied to the drive motor 20 and compressing device 30.

Although not illustrated in FIG. 7, the rotating speed of the drive motor 20 may be controlled in a more diversified fashion, using various frequencies of input electric power, to be applied to the drive motor 20, other than 20Hz, 60Hz, and 120Hz. In this case, it is also possible to prevent the drive motor 20 and compressing unit 30 from being overloaded by setting an appropriate operation condition such that the same compression capacity is obtained without an excessively high or low-speed rotation of the drive motor 20.

As apparent from the above description, the variable capacity rotary compressor according to the present invention can achieve a multi-stage variation in capacity thereof within a wide range while reducing a variation range of rotating speed, as compared to conventional cases, because it is possible not only to mechanically vary the capacity of the compressing device in accordance with a change of the rotating direction of the drive motor, but also to control the rotating speed of the drive motor in accordance with an electrical control method.

Since a multi-stage capacity variation within a wide range can be achieved without an excessively high or low-speed rotation of the drive motor, it is also possible to prevent the elements of the compressor from being overloaded, thereby achieving an extension of the lifespan of those elements and an improvement in the reliability of the compressor.

Although the preferred embodiments of the invention have been disclosed for illustrative purposes, those skilled in the art will appreciate that various modifications, additions and substitutions are possible, without departing from the scope and spirit of the invention as disclosed in the accompanying claims.